

## Measurement of bulk liver perfusion: initial assessment of agreement between ASL and phase-contrast MRI at 9.4T

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**Target audience:** Researchers studying arterial spin labelling, phase-contrast MRI, liver perfusion and liver disease.

**Purpose:** Non-invasive liver perfusion measurements could be used to monitor hepatic disease progression and drug efficacy in pre-clinical models such as cirrhosis [1] and liver metastases [2]. Arterial spin labelling (ASL) has been developed for use in the brain [3], heart [4] and kidney [5] to measure perfusion but has not yet found extensive utility in the liver, mainly due to its dual vascular supply and susceptibility to respiratory motion. Our previous work has demonstrated the utility of Look-Locker Flow-Sensitive Alternating Inversion Recovery (FAIR) mouse liver measurements [6]. Bulk liver perfusion can also be calculated from phase-contrast (PC) MRI measurements in the hepatic portal vein (PV), which provides 75% of the liver perfusion [7]. The measurement of PV flow using PC MRI is feasible at 9.4T, but has not, to date, been combined with ASL in a multi-metric approach to assess perfusion. This study aims to detect quantitative differences and agreement between methods within subjects.

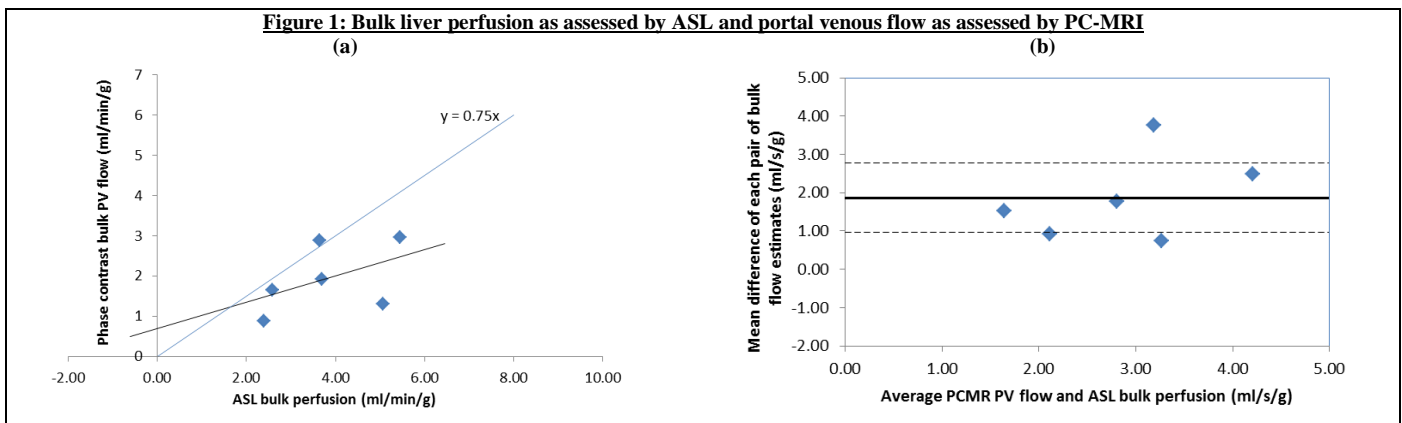
**Methods:** *In vivo measurements:* Scans were performed on a 9.4T Agilent VNMRs 20 cm horizontal-bore system, using a 72 mm birdcage coil. Rats were anaesthetised using 2% isoflurane in 100% O<sub>2</sub> and positioned in the centre of the magnet. Core body temperature was monitored and maintained using heated water pipes.

*PC-MRI acquisition:* PC-MRI vessel orthogonality was determined using Agilent's 3 point planning module. A respiratory-gated 2D PC sequence was used with the following acquisition parameters: 2 mm slice thickness,  $\alpha = 10^\circ$  and a 128 x 128 acquisition matrix. Velocity encoding settings were based on plug flow simulations of reported values of PV bulk flow and vessel diameter [8].

*ASL acquisition:* Single slice perfusion measurements were obtained using a respiratory-triggered inversion, segmented FAIR Look-Locker ASL sequence with a single-slice spoiled gradient-echo readout [6]. Sequence parameters were: FOV 60 x 60 mm<sup>2</sup>; matrix size 128 x 128; 2 mm slice, TE 1.18 ms; TI 110 ms; TR<sub>RF</sub> 2.3 ms;  $\alpha_{LL} = 8^\circ$ ; TR<sub>1</sub> 13 s; 50 inversion recovery readouts. Inversions were triggered at the end of the inspiration phase using respiratory gating apparatus (SA Instruments, US).

*Post-processing:* ASL perfusion maps were calculated using the Belle model [4]. A blood-tissue partition coefficient of 0.95 ml/g [9] was used and capillary blood T1 was assumed to be 1900ms [10], from previous measurements of the ventricular blood pool T1 in the mouse heart. Perfusion to the liver is assumed to be delivered from both the arterial and venous systems. For PC-MRI post-processing, regions of interest (ROIs) were selected over the portal vein and analysed using in house developed Matlab modules. Each recorded flow was the average of 3 measurements. All PC-MRI flow measurements were normalised to explanted (n=4) or estimated (n=2) liver weight [11].

**Results:** Mean bulk perfusion using ASL ( $3.81 \pm 1.25$  ml/min/g) exceeded mean bulk PV flow using PC-MRI ( $1.93 \pm 0.84$  ml/min/g) ( $p < 0.05$ ). Data is suggestive of a positive correlation (Figure 1a). A  $y = 0.75x$  line has been included on Fig.1a to demonstrate the expected correspondence between a portal perfusion and total liver perfusion. Bland-Altman analysis of the two measurements (Fig.1b) returned a mean difference of 1.8 ml/min/g, suggestive of ASL overestimation. The phase-contrast data compares very well with rat liver perfusion measured with <sup>85</sup>Krypton clearance [9].



**Discussion:** We have previously shown the feasibility of measuring localised liver perfusion using FAIR-ASL [6], an application that has not been extensively reported in the literature and have also demonstrated the feasibility of measuring bulk portal venous flow using PC-MRI. The ASL perfusion maps generated are from a mixture of both the arterial and portal systems: implementation of a pseudo-continuous ASL method is currently underway with a view to evaluate their respective contributions and directly compare these measurements with PC-MRI. The arterial spin labelling provided larger hepatic perfusion estimates although this could be amended with alternative quantification methods [12]. Larger scale studies comparing both sequences with gold-standard methods of assessing perfusion are required to determine the accuracy of each technique.

**Conclusion:** This is the first work to our knowledge of a multimetric approach to perfusion assessment of the liver. Our initial data suggests encouraging agreement between the two methods.

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